UPDATE ON THE RAFT RIVER GEOTHERMAL RESERVOIR

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ABSTRACT

Since the last conference, a fourth well has been drilled to an intermediate depth and tested as a production well, with plans to use this well in the long term for injection of fluids into the strata above the production strata. The third, triple legged well has been fully pump tested, and the recovery of the second well from an injection well back to production status has revealed very interesting data on the reservoir conditions around that well.

Both interference testing and geochemistry analysis shows that the third well is producing from a different aquifer from that supplying the No. 2 well. There is an effective barrier, yet unidentified as to structure, making pressure communication between these aquifers quite negligible. These results have led to significantly different models for the aquifer system than those previously believed to apply.

THE 4-WELL SYSTEM

The Raft River Geothermal Program now has 3 deep production wells, with producing zones between 3750 and 6000 ft. An intermediate depth well was recently drilled for injection testing into the zone between 1850 and 2500 ft. Figure 1 shows the location of the wells with respect to the major faults in the region. Figure 2 shows cross sections of each well. Additional details on these wells may be found in Reference 1 (last year's conference).

PRODUCTION TESTING

RRGE-1

This well has been used as a production well for the last 18 months, with greater than 95% on-line factor. It has been supplying fluids for a variety of heat exchanger tests, corrosion coupon tests, and water for several direct heat utilization experiments. Flow rates were deliberately throttled to supply only the fluids essential for these tests (150 to 300 gallons/minute (0 to 20 liters/sec), all using the artesian head. Pressures of 100 psig minimum have been maintained in all heat exchanger and coupon testing to prevent off-gasing and entry of air into these systems.

* This work has been performed under contract to the U.S. Department of Energy, Division of Geothermal Energy, and Idaho Operations Office.

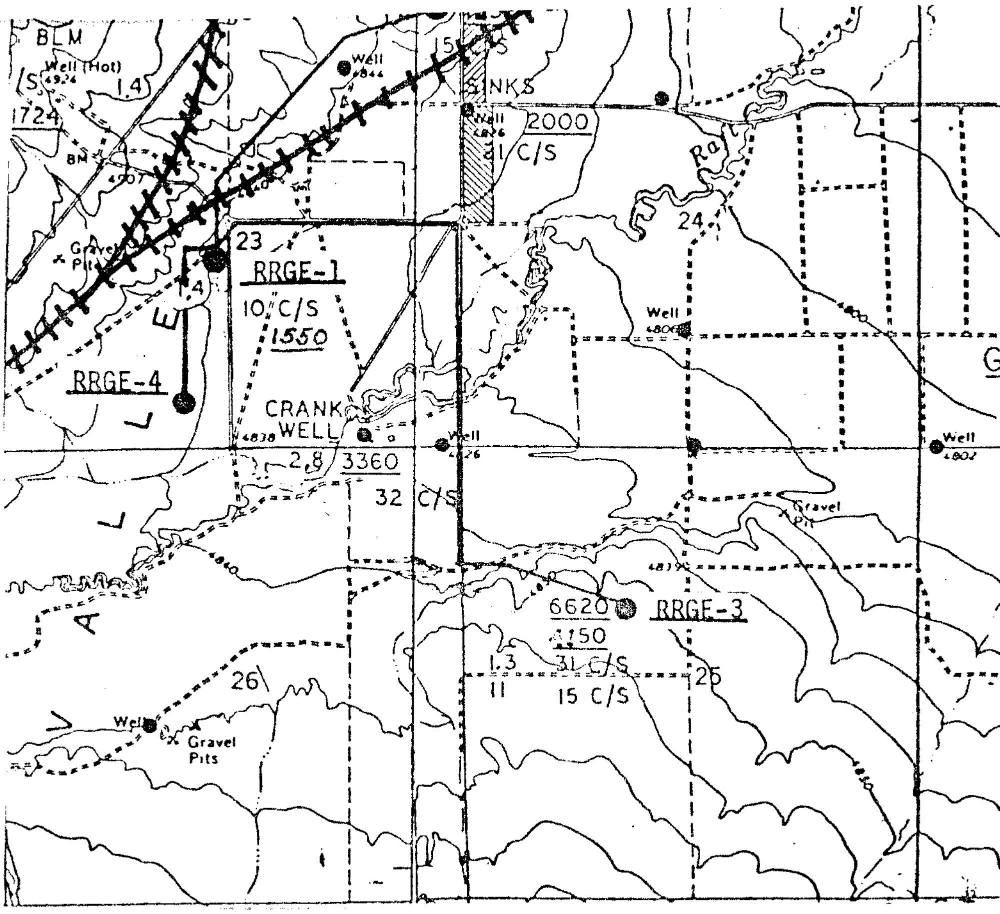
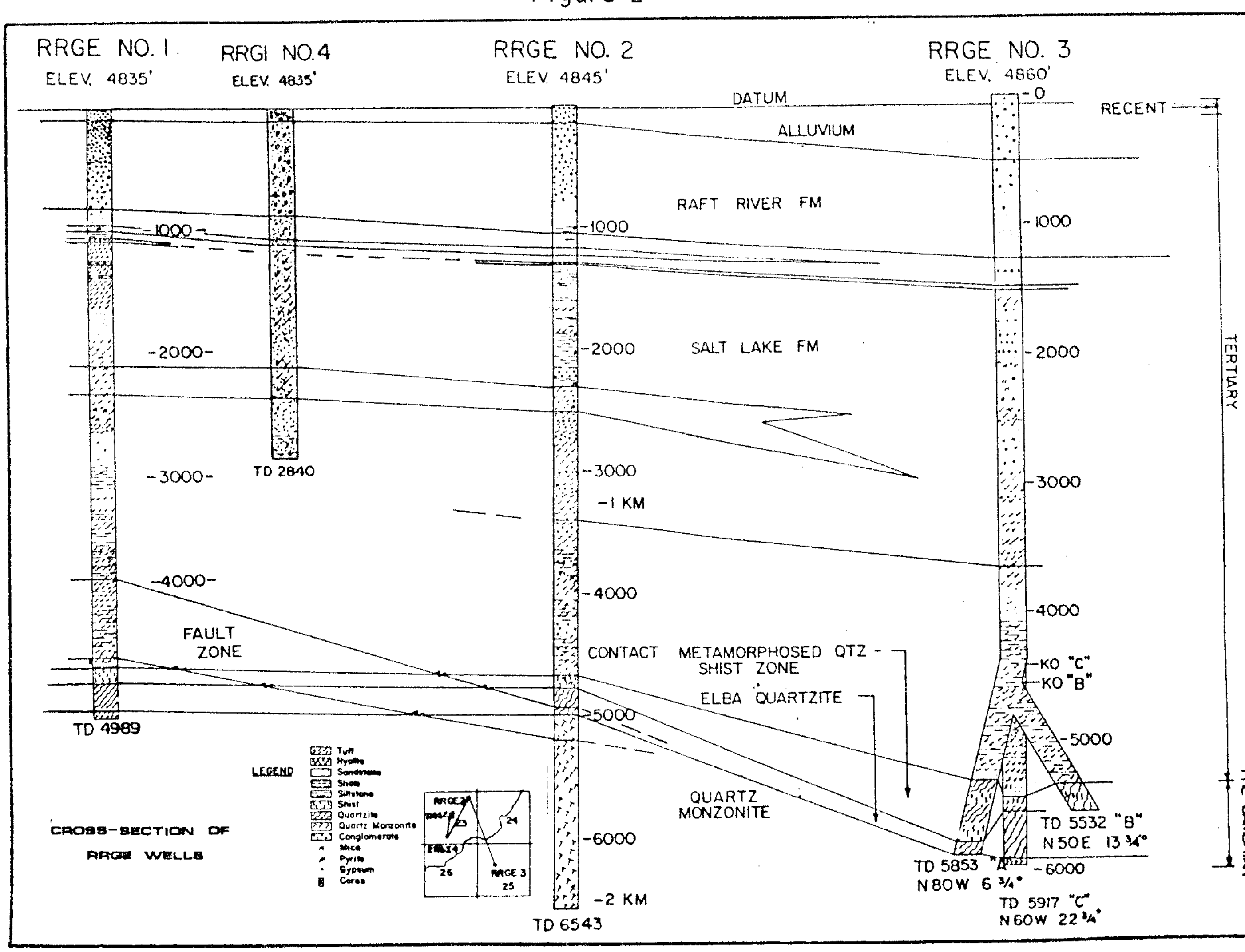


Figure 1

GEOCHEMICAL MAP
G₁ AREA
RAFT RIVER RESERVOIR

Figure 2



The well performance data during the 18 months has shown no decrease in productivity vs pressure, if anything a slight increase. The drawdown since the start of the long term operation is so far, on the time logarithmic scale. Short term fluctuations in flow (and hence pressure) have occurred as demanded by the variety of experiments, and are the predominant variable change.

The apparent productivity curve for this well is as shown in Figure 3. It is the most productive well in the reservoir. The chemistry of the fluids have remained essentially the same as after the first thorough flow testing, 2-1/2 years ago. Dissolved solids are 1550 ppm (mg/liter). Temperature has shown no change during this period. At these low flow rates, with the large 13-3/8 in. casing, the temperature loss in the well bore is only approximately 12°C (22°F). At the nominal design flow rate of 1200 gal/min (80 liters/sec) planned for this well with a pump in place, temperature loss should be reduced by nearly a factor of 4. Production zone temperatures have held at 147°C (296°F).

RRGE-2

No significant flow testing during the last 12 months. The usefulness of the prior injection testing in evaluating the production strata in the well is documented in Reference 4.

RRGE-3

A submersible pump was installed in this well at the 800 ft (244 m) level. Pump testing at 500 to 600 gal/min (90 l/sec) have been conducted for periods of several weeks to a month in duration. These have been at constant flow, using the Thies asymptotic semilogarithmic approach to obtain transmissivity and permeability thickness factors. Except for some possible early time effects before encountering a nearby boundary, the Thies analysis shows excellent linearly (semilog plot), giving a T = 850 ± 100 gal/day ft and kH - 8000 ± 1000 millidarcy-ft.

Pressure communication does not appear to occur, at least unambiguously over a two week period, with RRGE-2, 7000 ft away, as measured with a quartz transducer with ±0.01 psi sensitivity. Somewhat less ambiguous indication of pressure communication has been observed with the intermediate depth RRGI-4, 5000 ft away. The chemistry of the RRGE-3 well has been generally consistent throughout 1-1/2 years of limited testing (because of difficulty in disposing of the water) at 4150 ppm (mg/liter).

RRGI-4

This well was completed in May 1977, to be used for injection testing of the feasibility of disposing of water into the intermediate depth aquifer. It has 13-3/8 in. casing to 1835 ft, and is barefoot from there to its total present depth of 2840 ft. The relatively permeable section appears to extend from the casing bottom to about 2500 ft.* Though the well accepted

* When drilling out the shoe, the lower two sections of casing (80 ft total) dropped off and are wedged between 1895 and 1975 ft, effectively blocking out the formation in this region.

injected water quite readily, the production testing (the well has a hot artesian head of about 40 psig at 250°F) gave a transmissivity of 1600 ± 200 gal/day ft. This value is not much different from RRGE-2. The well has about 2300 ppm (mg/liter) solids coming from the producing region. It has slight pressure communication with RRGE-3, quite noticeable communication with the USGS No. 3 well (1300 ft deep, 2200 ft away), and no detectable communication to date with RRGE-1 or 2.

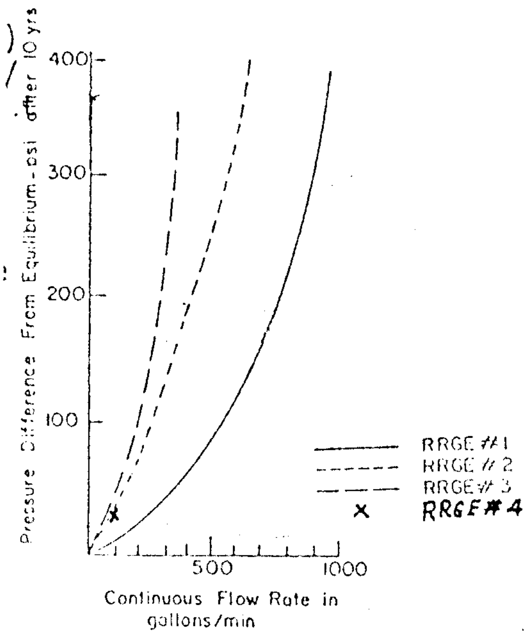


Figure 3 - Well productivity vs. drawdown after constant flow for 10 yr period. Note: Wells 1, 2, 3 have a positive (artesian) head of 150 psig when at hot "equilibrium." The 4th well has an artesian head of 40 psig.

GEOCHEMISTRY

The chemistry of the waters produced from the three deep wells and the Crank (400 ft or 122m) and BLM (500 ft or 152m) wells has shown that the chemical species in these wells seem to be originating from two quite different systems. The one has chemistry similar to RRGE-3 (4150 ppm), the other similar to RRGE-2 (1250 ppm). RRGE-1, the BLM, and the Crank wells appear to be mistures of these two systems, as shown in Table 1. In that Table, X_m represents the fractional contribution from the system representative of RRGE-2.

It thus appears that the most chemical laden waters and those with the highest indicated reservoir temperatures are upwelling in the region of RRGE-3 and the Crank well, and leaking into the area near RRGE-1 and the BLM well. Much purer waters are apparently feeding RRGE-2 (to the northeast) and leaking into the BLM and RRGE-1 areas. RRGI-4, for the little it has flowed, also seems to be composed of both waters.

CONCLUSIONS

The long hypothesized model of the geothermal heat source being located away from the immediate area, with the hot waters being fed into the region of the wells via the "narrows" structure to the southwest, is not completely supported by the geochemical analysis. Instead, it would seem that a modified model would be that of a hot plate effect under much of the valley, with a localized somewhat hotter, poorly convective region near RRGE-3.

JFK

TABLE I

TOTAL DISSOLVED SOLIDS AND MIXING FRACTIONS
IN THE RAFT RIVER WELLS

	RRGE-2	RRGE-1	BLM	Crank	RRGE-3
TDS	1267	1560	1640	3720	4130
X_m	1	.898	.870	.143	0
Apparent Reservoir Temperature					
S_iO_2	158°C	155°C	--	--	165°C
Na/K/Ca	185°C	180°C	--	--	190°C

It does appear that a barrier of some type exists between RRGE-3 and the other two deep wells, restricting both pressure and flow communication, isolating the two systems with quite distinctly different chemistry.

Finally, the longer term tests have not shown any major boundary restrictions or significant regions of highly channelled (non-isotropic) flow. Based on these tentative conclusions and the information presented in Ref. 1, one can conclude the following about the known reservoir, that within a mile of the existing three wells.

Minimum area of Known reservoir ∿ 5 sq mi. (2)

Geothermal Aquifer Capacity - 300,000 acre-ft, with effective porosity of ∿ 0.15.

Near surface aquifer that may supply the geothermal aquifer containing about 12 million acre ft, and sees annual precipitation of 200,000 acre ft (2) (the entire southern Raft River Valley of about 100 sq

Geothermal aquifer heat content (known reservoir only, heat above 250°F only) = 0.5 Quad or 160 MW-Centuries (about 20 MW-Centuries net electrical output with binary-isobutane conversion system.

REFERENCE

1. D. Goldman, J. F. Kunze, L. G. Miller, R. C. Stoker, "Studies on the 3-Well Reservoir System in Raft River, 2nd Workshop on Geothermal Reservoir Engineering, Stanford University 1976.

2. Geothermal R&D Project Report for October 1976 to March 1977, TREE-1134, EG&G Idaho, Inc.

3. E. H. Walker, L. C. Dutcher, S. O. Decker, and K. L. Dyer, The Raft River Basin, Water Intermountain Bulletin No. 19, State Department of Water Resources (1970).

4. J. F. Kunze, R. C. Stoker, D. Goldman, "Heat Transfer in Formation as a Geothermal Reservoir Engineering Tool," 17th Heat Transfer Conference of ASME and AICHE, August 1977.